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Diagnosing climate change impacts and identifying adaptation strategies by involving key stakeholder organisations and farmers in Sikkim, India: Challenges and opportunities

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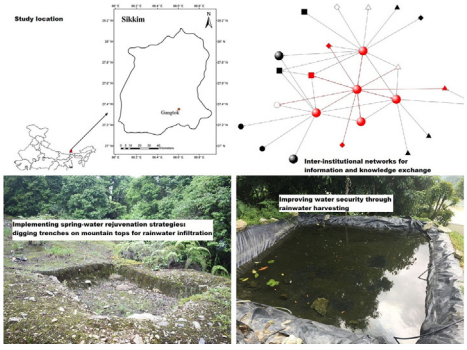
HIGHLIGHTS

- A case study involving key stakeholders in understanding climate change impacts and identifying adaptation strategies
- Demonstrates how the gaps between research, policy and adaptation implementation needs to be narrowed
- Farmers with limited climate change awareness benefits from social networks and adaptation trainings by government
- Highly relevant for both policymakers and researchers because it identifies research needs from stakeholders' perspectives

GRAPHICAL ABSTRACT



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ABSTRACT

Narrowing the gap between research, policy making and implementing adaptation remains a challenge in many parts of the world where climate change is likely to severely impact water security. This research aims to narrow this gap by matching the adaptation strategies being framed by policy makers to that of the perspectives of development agencies, researchers and farmers in the Himalayan state of Sikkim in India.

Our case study examined the perspectives of various stakeholders for climate change impacts, current adaptation strategies, knowledge gaps and adaptation barriers, particularly in the context of implementing the Sikkim State Action Plan on Climate Change through semi-structured interviews carried out with decision makers in the Sikkim State Government, researchers, consultants, local academia, development agencies and farmers. Using Stakeholders Network Analysis tools, this research unravels the complexities of perceiving climate change impacts, identifying strategies, and implementing adaptation. While farmers are less aware about the global phenomenon of climate change impacts for water security, their knowledge of the local conditions and their close interaction with the State Government Agriculture Department provides them opportunities. Although important steps are being initiated through the Sikkim State Action Plan on Climate Change it is yet to deliver effective means of adaptation implementation and hence, strengthening the networks of close coordination between the various implementing agencies will pay dividends. Knowledge gaps and the need for capacity building identified in this research, based on the understandings of key stakeholders are highly relevant to both the research community and for informing policy.

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1. Introduction

The immediate impacts of climate change are generally experienced through the medium of water (IPCC, 2014a; Olmstead, 2014). Floods and droughts are the immediate and visible impacts generally associated with climate change (Goodess, 2012). Subsistence agriculture in mountainous regions where irrigation infrastructure is limited or absent and dependent on natural rainfall and spring water is likely to be among the most vulnerable to climate change and variability (Brown et al., 2013; Misra, 2012). Such impacts are likely to cause other challenges leading to migration and instability in the society (IPCC, 2014a). For setting the priorities of adaptation strategies it is necessary to identify and characterise communities, regions and agricultural systems that are most vulnerable to climate change (Holler, 2014). Since vulnerability is a function of adaptive capacity (Hinkel, 2011), besides the global impacts of climate change, it varies across regions, communities and sectors. Studies incorporating the risks of climate change among communities dependent on subsistence agriculture will enable the designing of effective policies (Spires et al., 2014) and also the identification of key and urgent research areas which are suitable to the contextual needs (Azhoni et al., 2017b). Such studies will require the perspectives of various stakeholders; including the perspectives of the members for whom the adaption plan is particularly targeted (Bhave et al., 2014).

The impacts of climate change, such as erratic precipitation and increasing temperatures are particularly going to be harsh on the rural communities living in mountain regions and depending on subsistence agriculture for livelihood. This is particularly so in tropical regions where water availability, droughts and floods are the mediums through which the climate change impacts will have devastating impacts on such communities. The international community has invested a lot of energy and resources both on understanding the impacts of climate change and in assisting adaptation measures besides mitigation (IPCC, 2014b). Many countries, including India, has initiated adaptation strategies with the involvement of various stakeholders in different sectors but particularly for water security (Azhoni et al., 2017a) besides mitigation. However, trickling down such benefits to many vulnerable communities, especially in regions that are dependent on subsistence agriculture in mountainous regions (Ford et al., 2014), are often challenging due to lack connectivity. Effective adaptive strategies that can be implemented locally for addressing the immediate impacts are lacking (Iglesias and Garrote, 2015). Such adaptation strategies need to take into account the local contextual needs (Azhoni et al., 2017b) and challenges because although climate change is a global phenomenon the impacts are experienced locally and variably. Moreover, due to the variation in adaptive capacity, the consequences of climate change impacts are experienced variably (Schneiderbauer et al., 2013).

The efforts and strategies to enable local communities to address climate change impacts are generally guided by the researcher-led decisions which decide the types of technologies and strategies which are expected to be adopted and implemented by the vulnerable communities. This approach has proved inefficient (Biesbroek et al., 2013) because the strategies identified by researchers are not adopted by the targeted communities (Rastogi, 2011) either due to lack of adequate understanding of the needs of the vulnerable communities or the inability to grasp and adopt the adaptation strategies identified and suggested by researchers and policy makers or the lack of funds (Porter et al., 2015). This has ended up in low adoption of the strategies initiated by the government in the past (Azhoni et al., 2017b). For example, in the country-wide survey by four Indian Institutes of Management on the increasing gap between the irrigation capacity created and capacity utilised, it has been observed that the targeted communities, farmers in this context, are not utilising the irrigation capacity created (IIM Kolkata, 2008). One of the reasons for this gap, it was pointed out, was the mismatch between the needs perceived by the project proponents, government departments and policy makers, and the beneficiaries (in this case farmers) (IIM Kolkata, 2008). Moreover, earlier studies have shown that public participation in any project enables a more acceptable and successful implementation (Warner, 2006) when the various stakeholders are taken into confidence (Wesselink et al., 2011). Public participation enhances trust, the sense of ownership and justifies decisions which ultimately lead to a more effective implementation of plans and strategies (Wesselink et al., 2011). On the other hand, non-experts can also identify blind-spots and lacunae which the experts might take for granted or overlooked (Wesselink et al., 2011).

In this paper, we aim to identify climate change impacts and adaptation opportunities through the perspectives of key stakeholder members in a particular region to avoid maladaptation. We propose to do this through a case study which explores the perspective of various stakeholders in a particular politically defined area so that the gap between research, policy making and adaptation implementation can be bridged. Therefore, this paper reports the findings from a participatory research framework done in the Himalayan state of Sikkim in north-east India and demonstrates the importance of involving various stakeholders in climate change adaptation planning and implementation.

1.1. The case study area: Sikkim

The mountainous State of Sikkim, lying in the eastern Himalayan region of India (Fig. 1), which was earlier ruled by monarch, joined the Union of India in 1975, and has about half a million population as per 2011 census and total geographical area of 7096 sq·km. The state is divided into four districts namely North, South, East and West District with the state capital at Gangtok in the East District which is a tourist destination. About 70% of its population is in the rural areas with livelihoods linked to agriculture and forest products which are highly climate sensitive. Since the state is highly agriculture dependent, with rice and maize as main crops, more than 98% of water use is for irrigation (Government of Sikkim, 2012) and about 20% of the state geographical area is used for cultivation. Due to steeply sloping landforms water loss and soil erosion is common and wet cultivation of rice is done on terraced fields which are dependent on timely seasonal rainfall and spring water emanating naturally from unconfined aquifers.

Climate change impacts poses a considerable threat to this tiny Himalayan state (Jain et al., 2013) with glacier covered mountains in the north that form more than 315 glacial lakes (Government of Sikkim, 2012) which can result into glacier lake outburst floods (Ives et al., 2010) in the downstream. Moreover, the melting of snows in the north will potentially effect changes in seasonal river discharges affecting the long-term efficiency of hydropower dams that depend on reliable river discharge (Jeelani et al., 2012). Rainfall trend analysis in this part of the Eastern Himalayas indicates a change in the precipitation pattern (Singh and Goyal, 2016) and also projects a more erratic pattern in the near future (Government of Sikkim, 2012). Drying up of spring water sources from unconfined aquifers which are highly dependent on rainfall have been reported in recent studies (Tambe et al., 2012). Increased crop water requirement (Biemans et al., 2013) due to increasing temperature and reduced availability of spring-water (Jeelani et al., 2012) and rainfall variability could have a serious impact on the socio-cultural and economic life in the state that could lead to migration and other instabilities (Goodess, 2012). Therefore, climate change adaptation strategies for addressing these challenges by taking into consideration the local contextual needs are urgently required to be developed for enabling policy makers and development agencies to adopt suitable adaptation strategies. This research aims to bridge this gap by taking into consideration the perspectives of key stakeholder members within the state of Sikkim.

1.2. Governance structure of Sikkim in relation to water and climate change

Water is a state subject as per the constitution of India and hence state governments are responsible for provision of water supply both

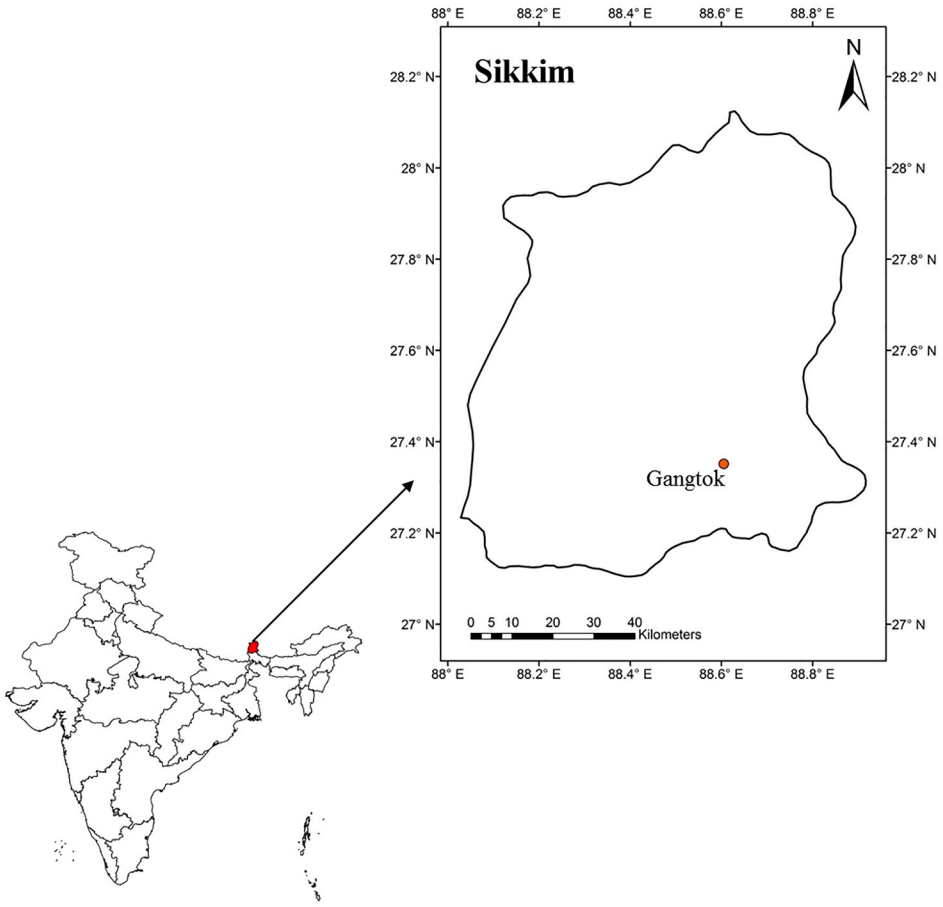

Fig. 1. Map of Sikkim - the study location.

for domestic and industrial use as well as for agriculture. As climate change impacts are generally experienced mostly through the medium of water, adapting water management to climate change also forms a key responsibility of the state government (Azhoni et al., 2017a). In order to address the challenges of climate change Sikkim has framed the State Action Plan on Climate Change in 2012 (Government of Sikkim, 2012) with water security being one of its main agenda. The State Department of Science, Technology & Climate Change (DSTCC) is mandated to coordinate the implementation of the State Action Plan on Climate Change. While the Rural Management and Development Department (RMDD) is responsible for rural development, including rural water supply, and Water Security and Public Health Engineering (PHE) Department carries out the water supply to the urban and semi-urban areas of Sikkim. Irrigation & Flood Control Department carries out the construction of irrigation works and its maintenance and assessment and development of flood control measures. On the other hand, Land Revenue and Disaster Management Department is primarily concerned with maintenance of land records and enforcement of land laws which also includes the prevention of disasters and providing immediate relief to the victims in post-disaster scenarios.

Forests, Environment & Wildlife Management Department liaises with the Union Ministry of Environment, Forest and Climate Change in forest conservation, planning and promotion of wildlife and biodiversity conservation in the state. The Department of Food Security & Agriculture Development in the State, on the other hand, is mandated to provide services to the farming communities by improving the overall capacity including through the use of ICT and other mediums and training workshops for the farmers in the state. Besides these state government Departments, there are other Central Government agencies such as Central Groundwater Board which monitors the groundwater situation all over the country and development agencies, including international organisations, are operating in the State which assist the state government in development of water infrastructure. All these state government departments and other organisations are important stakeholders for water management in the state besides the farmers and other communities living in the State.

2. Methods

Since the inclusion of all key stakeholders from the very initiation stage of any project conceptualisation is crucial this research identify the contextual knowledge gaps which researchers can develop and identify adaptation strategies for better adoption. Therefore, a participatory model of identifying the local contextual situations by including the perspectives of the key stakeholders, policy makers in the government, educational & research institutions, implementing agencies of the state government and development organisations and agencies in the locality was adopted and developed.

Interviews can provide valuable information regarding the practice and implementation of climate change adaptation beyond what the written documents can reveal (Chirban, 1996). It provides an opportunity for the researcher to probe deeper into the issues and challenges of implementing the aims and strategies laid out in the government documents (Gillham, 2004). Besides what the interview respondents say, who says it also bears significance in climate change adaptation project implementations because that indicates the seriousness and involvement in addressing the impacts (Never, 2012). Moreover, since the powers and influence of each stakeholder is different, who believes what is important also plays a key role in the decision making (Ballejos and Montagna, 2008). Therefore, in this research attempts

have been made to ensure that the information regarding the perceptions of climate change impacts are collected from the persons who are expected to (or should) influence the decisions in the adaptation planning and implementation at various levels in the state. These are discussed below.

2.1. Data collection

In order to ascertain the level of climate change awareness and the concerns and perspectives of the local people, a fieldwork was carried out during the month of June, 2017. Meetings were conducted with officials from ten state government departments, three farmer households, one research & educational institution and two development agencies. These (State) government departments and organisations include the Department of Science, Technology & Climate Change, Rural Management and Development Department, Forest Environment and Wildlife Department, Food Security and Agriculture Department, Water Security &Public Health Engineering Department, Water Resources and River Development Department, District Officials from each of the four districts, Sikkim University, and three farmer households in various parts of South District and United Nations Development Program (UNDP). The farmers of South District were selected because the interviewed government officials pointed out that it is the district more prone to drought situations in the past and more agriculture activities are concentrated in this district. No Central Government organisation officials and other organisations which do not have their offices in Sikkim are interviewed for this research. Since the State Department of Science, Technology & Climate Change is mandated to implement the State Action Plan on Climate, with water security being one its main concern, this department was first contacted and through them other key state government departments and officials were identified. The first few meeting appointments were made through email and telephone and the remaining were through personal contact and recommendations of the officials interviewed earlier. This ensured that the State Government departments and other (international and development) organisations which are involved with the State Government in the climate change related activities are included in the interview. Farmers were identified with the aid of the State Agriculture Department and other farmers are identified through the later. This also provided a perspective of the social network among the officials and key stakeholders. The total time of interaction was 6 h and 12 min and each interview ranged from 15 min to 85 min. After discussing the State Government initiatives and strategies for addressing the climate change impacts, other departments and organisations that are involved in the climate change related activities in the State were also identified.

The semi-structured interview discussions include their perception and awareness about the potential impacts of climate change, the vulnerable regions in Sikkim for agriculture, and other activities and initiatives being taken by the respective department or organisation or in collaboration with other departments and organisations. Questions of the semi-structured interviews, which were not necessarily sequential (being a semi-structured interview), are provided as a Supplementary material in Appendix A. One of the key points of discussion was their awareness and level of involvement in the State Action Plan on Climate Change and its associated challenges of implementation. Besides the Strategies being adopted for climate change adaptation, the interview discussions also included the kind of support they take from other departments or research organisations and their interactions with farmers and other Stakeholders. Moreover, their challenges of addressing climate variability and weather-related hazards were also discussed.

With the farmers, the main points of discussion were the kinds of assistances they receive from government departments and development agencies apart from assessing their perceptions about the potential impacts of climate change and how they are addressing them. Their perceptions about the results of spring water rejuvenation projects being carried out in their areas were also discussed besides the kinds of trainings in regards to agricultural practices they have received from government organised workshops and awareness training programs.

2.2. Data analysis

The semi-structured interviews conducted with key officials in various departments and organisations in the state capital, district officials from the four districts of Sikkim and farmers are transcribed verbatim and analysed with an aim to deduce their perceptions of climate change impacts, coordination with other stakeholders and the challenges of adaptation implementation. Perspectives of officials from various agencies and departments are contrasted and compared in order to triangulate the findings and also to assess the level of awareness and initiatives being undertaken by them. In addition, key challenges of climate change adaptation are identified through the analysis of their perspectives. The interview data is analysed to specifically identify: concerns, initiatives, challenges, networks, and opportunities and codified with colours to quickly retrieve back the text from the original interview transcripts. In order to maintain the anonymity of the respondents, their comments have been codified with acronyms such as FA for farmers, State Government Departments at the State Capital with SG, District Officials (at District Head Quarters) as DO, with Research Institution with RI, and (non-governmental) Development and Consulting Organisations with NG. These alphabets are accompanied by numerals to differentiate the different respondents from similar types of organisations. The following sections present these findings which are followed by discussion in Section 4.

3. Results: findings from interactions with key stakeholders

Preliminary survey indicates a limited awareness of climate change impacts among farmers but highly relevant awareness among government officials in the key government departments. Various programs have been initiated in the State to address extreme weather-related events. Some of the key climate change adaptation challenges and knowledge and information gaps identified through the interaction with key stakeholders in the state are elaborated in the succeeding sections.

When asked about the most vulnerable regions of the state, the respondents from the State Government Departments at the capital and other district officials pointed out that the state in some regions, such as the South District where subsistence agriculture is a common occupation, have been facing erratic rainfalls and drought like situations in the past decade which are being linked to climate change impacts. These respondents believe that the South District is particularly vulnerable to climate change as it is highly dependent on the rainfall and springwater for irrigation as well as for domestic water supply. It was also pointed out that this region is most vulnerable to the changing climate due to a number of socio-economic reasons in addition to geophysical features. Many subsistence farmers in the South District faces the challenges of climate change impacts that could lead to other sociological issues such as migration and displacement in the region.

3.1. Key concerns of climate change impacts

Most of the interview respondent, besides a few farmers, indicated that they are aware of the potential impacts of climate change in the State. Most of these State Government officials are in the responsible positions and also have been working in this area for some years. Some respondents raised the need to create climate change impacts awareness programs in the state. The respondents raised a number of concerns which are triggered by or related to climate change impacts out of which the more prominent ones can be summarised as follows.

3.1.1. Drying up of spring-water sources

Since the main source of water, both for drinking and irrigation, is dependent on the spring water, one of the key concerns of the respondents, officials from the state government department as well as farmers, is the perceived decreasing spring sources. Respondents (specifically SG02 and SG5) stated that although they do not have historical records of the volume of discharge from spring sources, it is widely perceived and attested by the village communities that spring sources have dried up in many locations and this is being linked to climate change. Some other respondents (RA14 and SG08) also attributed it to other impacts including construction of hydropower dams and other developmental projects besides climate change as among the possible causes of the retreating spring-water in the state. Migration and internal displacements resulting from the lack of perennial sources of water in the rural areas were also identified by some respondents (FA15, RA14 and NG13) as potential threats of climate change impacts. For example, one of the respondent state: "*If all the springs … dries up, there is no alternative but to migrate*." (FA15).

3.1.2. Erratic rainfall

Sikkim is mostly dependent on rainwater for irrigation. Due to the steep terrain, both domestic water supply and irrigation is mostly gravity fed and sourced from stream sources which are in turn collected from spring sources in mountain gorges. Since these spring sources are dependent on the rainfall that enables the recharge of mountain aquifers, timely rainfall is considered to be very crucial. Rainfall in the region is not just for direct irrigation of the crops on sloppy mountains but also for recharging the spring sources that give rise to streams from which water is drawn out through gravity. Subsistence agriculture which is dependent on the rainfall and the domestic water supply which is dependent on the spring water is perceived to be threatened by climate change.

Sikkim is investing heavily on the hydropower potential in the state. Respondents from the government departments and researchers (RA15, SG01 and SG09) raise concern regarding the climate change impacts on these hydropower projects. An uncertain climate meant the unreliable supply of water. Sediments due to floods and inadequate rainfall during the dry season are other concerns identified to have potential serious impact on the hydropower infrastructure being developed in the state. A respondent put across this concern: "*The precipitation regime is changing. Sometimes a lot of rainfall, even in extreme or even the snowfall is not confining to the normal; too late or too much.*" Such "*heavy precipitation would result in floods…*" (SG02) leading to higher deposition of sediments during the rainy seasons.

3.1.3. Glacier retreat and glacier lake outbursts

The northern and higher altitude of the state is mostly covered with snow and glaciers throughout the year. These snow mountains give rise to big rivers such, as the Teesta River, over which a number of hydropower projects are being constructed. The retreatment of glaciers will have a serious impact on the hydropower projects. Respondents (NG13, DO11) raise concerns of the possible impacts of climate change for the sustainability of these hydropower dams.

Besides the impacts on the hydropower stations due to the changing seasonal flow of river discharge due to the early melting of snow or the late formation of snows, formation of glacial lakes and moraine dams is another primary concern reported by the respondents (SG01, SG02 and RA14). The State government, with the assistance of the Central Government agencies, has initiated actions to avoid glacial lake outburst floods (GLOF) in the downstream (SG01). This includes the siphoning of glacial lake formed by moraine dams.

3.1.4. Other challenges and cascading impacts

The respondents also raised other concerns of the impacts of climate change besides drying up spring sources, glacial lake outbursts and erratic rainfall and the changing monsoon season and the shortening winter season in the state. Forest fire, drought situations, changing land-use patterns which are perceived to be triggered both by climate change and developmental activities are other areas of raised by the interview respondents (SG08). The impacts on the ecological biodiversity and vegetation in the state were other concerns raised by the respondents (SG08). Besides the impacts of climate change, some other respondents (RA14) pointed to the non-climatic impacts such as construction of hydropower dams and roads as a potential source affecting the state: "*People would say because of the climate change. But that is not the only reason… constructions…*" (RA14) Changes in forest vegetation and ecosystem were other concerns shared by the respondents (RA14 and SG08).

3.2. Key Initiatives being taken to address climate change impacts

The State Department of Science, Technology and Climate Change is mandated to a) carry out vulnerability assessments, b) create social awareness about the impacts of climate change, c) initiate and coordinate meetings with other stakeholders and d) to carry out training and capacity building exercises. For carrying out the vulnerability assessment, baseline data are being carried out because they lacked other historical data including land-use and land-cover and the availability of water sources at various locations in the state (SG02 and SG03). The department is also coordinating and acquiring socio-economic information from other State Government Departments, such as Statistical and Monitoring Department. For raising public awareness about the potential impacts of climate change in the state, the State Department of Science & Technology Climate Change Cell coordinates with Block Administrative Centres and schools. Booklets for raising awareness among the school children are also being published and distributed among the general public. Perceiving a gap between the scientific community and the local media (SG02), the Department has also organised media workshops to raise awareness about the potential impacts of climate change in the state.

Besides the Department of Science, Technology and Climate Change, Rural Management and Development Department (RMDD), Agriculture Department and Forest Department play an important role in the State climate change adaptation, particularly among the rural communities. Some other initiatives which the RMDD stated to have initiated for the future includes: *install*[ing] *some gauges*, *climatic spring gauges*, *under this climate change fund* (SG05) for monitoring of spring water discharge.

Three particular actions being initiated by the State Government which can be related to climate change impacts are worth taking note. These are listed and elaborated.

a) **State action plan on climate change** being formulated and coordinated by the Department of Science, Technology and Climate Change.

The formulation of the State Action Plan on Climate Change, being coordinated by the State Department of Science, Technology and Climate Change is a major initiative of the state government. It was conceived as a top-down approach initiated by the Union Ministry of Environment and Forest in 2012. The formulation of the State Action Plan on Climate Change was assisted by the German development agency, GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit). The State is at the initial stage of the implementation.

The findings from the preliminary survey with all the different types of stakeholders in the State reveals a number of issues that need to be taken up for future research works. The implementation of State Action Plan on Climate Change is still at an initial stage and hence the level of awareness and involvement by the other State Government Departments, besides the coordinating department, which the Department of Science, Technology and Climate Change is lacking.

b) **Hazard risk and vulnerability assessment** being undertaken by the Land Revenue Department with the assistance of TARU.

The HRAVA is flagship program of the state government being implemented through the State Department of Land Revenue and Disaster Management. The assessment of the hazard risk and vulnerability was carried out by the consultant, TARU. The consultant has assessed the potential risks and vulnerability and documented them. Workshops and mock drills are being carried out to address some of the potential hazards such as floods and earthquakes which are not all necessarily triggered by climate change alone. Hazard Risk and Vulnerability Assessment under the Land Revenue and Disaster management, which has identified vulnerable zones, are being initiated and information made available to other District Head Quarters. This is not being called a climate change adaptation initiative as such. However, since it overlaps with climate related hazards it has the potential to address some of the impacts of climate change. However, this does not include the potential impacts of climate change on crop water requirement in the state.

c) **Spring water rejuvenation** under the Rural Management and Development Department.

The State Government, through the Rural Management and Development Department (RMDD), have undertaken many projects for spring-water rejuvenation in the South District to combat the decreasing availability of spring-water in the region through the National Rural Employment Guarantee Scheme. The concept of digging trenches in the mountain tops to improve the infiltration of rainwater into the mountain aquifers to improve the spring-water is locally known as *Dhara Vikas*. Many officials in various government departments (SG01, SG04, SG05 and DO12) refer this as an example of addressing climate change impacts on water availability particularly in the rural areas both for domestic supply as well as the agricultural irrigation. Farmers believe it has improved the spring water discharge in the locality. However, no detail scientific studies have been done so far to assess the actual impacts of this spring water rejuvenations by digging trenches in the ground has been carried out (SG03). It is not known how it is impacting the aquifers in the region (SG05). In order to improve and publicise this concept of improving the spring-water, open access websites are also being launched to provide accessible information and awareness about the potential benefits of digging trenches on the mountain tops for improving the spring-water in the foothills.

3.3. Inter-institutional networks and coordination

Coordination between key stakeholder organisations being an important means for acquiring information and resources in climate change adaptation it is crucial to identify key individuals and organisations that bridge the gap between various actors and stakeholders. There are individuals who recognise the importance of such "bridges": "*I am sort of the bridge between the different government organisations and UNDP*" (NG13). Moreover, networks and the effectiveness of coordination between various types of stakeholders and organisations are the mediums through which resources – information, practices, knowledge and financial – are acquired. Respondents generally have a positive impression when it comes to accessibility and they believe that makes their work in Sikkim less arduous: "*… generally in Sikkim, you don't have so much of red-tapism and bureaucracy. So you do have an easy access and it's a very informal culture.*" (NG13). However, not every respondent agrees about the smoothness of coordination and accessibility. Some others (RA14, SG02 and SG03) pointed out the lack of coordination as a challenge. The challenges that emerge from weak or inadequate coordination are further presented in Section 3.4.4.

Fig. 2 shows the network between the key State Government Departments (indicated by Spheres), Financial/Banking institutions (diamond), Farmers (circle), Union Government Ministries/institutions (square), Research and/or Educational institutions (triangle), and consulting and development agencies (disc). The organisations and persons mentioned by the respondents are represented here in the Fig. 2 but not all of them have been interviewed. The direction of the arrow points to the agency/department with whom the interview respondent from the other end stated to be interacting or taking the assistance for climate change and water management related activities. The assistances or exchange of resources are in various forms; financial as well as information, knowledge and expertise.

As the network diagram in Fig. 1 suggests, only two state government departments interact with the farmers directly. The State Government Departments (indicated by Spheres in the figure) such as Department of Science & Technology, Rural Management and Development Department and Agriculture Department being the main coordinating agencies, it has more network connectivity with other stakeholders. During the interaction with the farmers, it was apparent that they benefit from attending trainings and workshops conducted by the State Agriculture Department. The spring-water rejuvenation projects, called locally as *Dhara Vikas*, was also stated to be beneficial when it was executed in coordination with the District Administration and the Rural Management and Development Department. Some of the farmers also stated the importance of social network among themselves through which they get to know about climate resilient crops and farming methods.

3.4. Identified key adaptation challenges

3.4.1. Lack of information and data

One of the perennial key challenge of climate change is the lack of historical data, reliable socio-economic data and uncertainties in the projected climate change and the lack of a fine resolution by which local agencies can plan anticipatory adaptation strategies. Many respondents referred this as the key challenge: "*the constrain is very limited … meteorological data… Some are there but …* [of] *very short durations only*" (SG02).

Similarly, with respect to spring-water rejuvenation projects one of the officials stated: "*the major problems in spring-shed management is we don't have the data*" (SG03). The success stories about the rainwater rejuvenation projects are: "*from the people's perception. Our program is becoming successful…*" (SG05) and empirical studies are lacking to fully understand the impacts of these initiatives.

On the other hand, projected climate information available with policy makers in the state are of "*…very course resolution…* [and] *we do not have such kinds of field data*" (SG02). This is linked to the lack of weather monitoring stations in the state: "*We don't have good weather station. We don't have a data… in different parts of the states…these are some of the disconnects.*" (RA14). One of the respondents pointed to the accessibility of even the existing available with the India Meteorological Department (IMD): "*Main problem with IMD data is that it is very difficult to get. A lot of procedures and formalities is there. Even after fulfilling all those formalities it is very difficult. For example, we even wrote one letter two years back, to IMD through the Sikkim Government and faxed many times. Emailed and contacted and we are willing to purchase your data. But they are not willing to give us. They are not giving any response. That is the main problem*" (SG02). Another respondent from a State Government department stated that: "*now We do have installed 15 automatic weather stations. But few days back of the … has indicated that the data accuracy has to be authenticated* (SG01). When asked about the meteorological collected by other agencies, the earlier respondent replied that: *…data is very small and short durations only. So we are lacking on climatic data – observed climatic data*" (SG02).

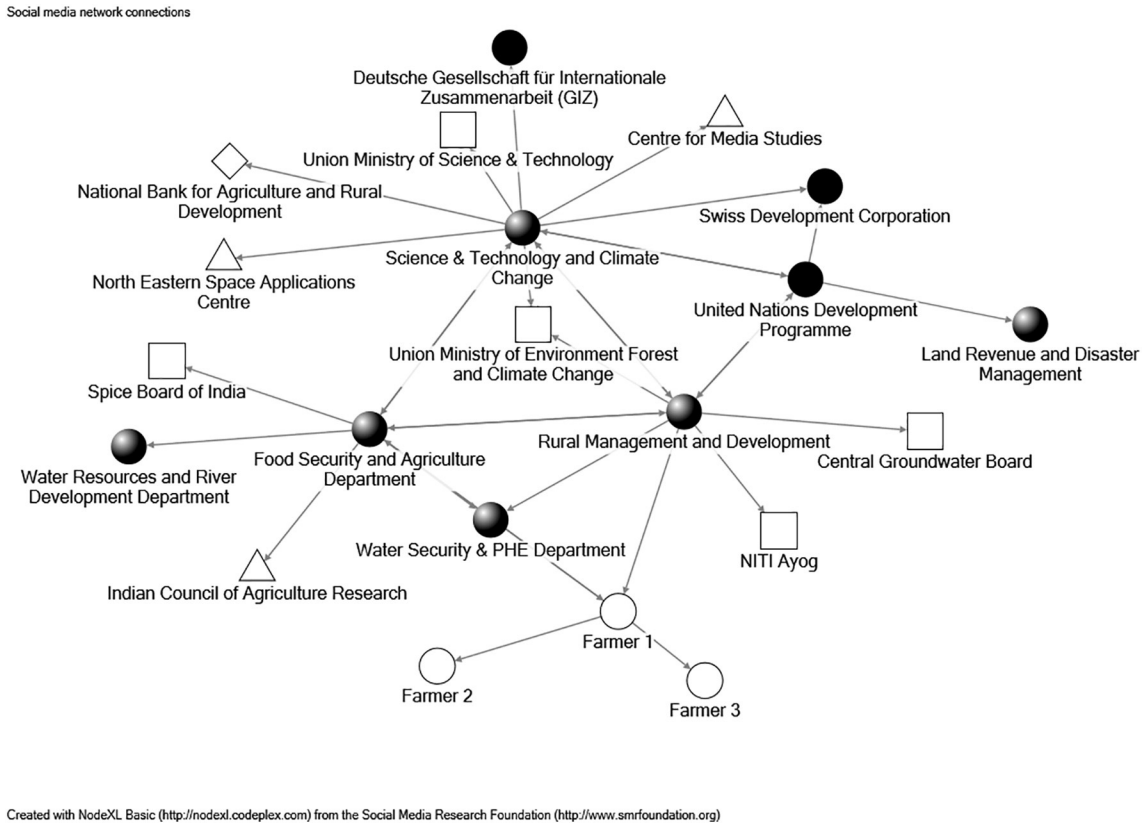

Fig. 2. Inter-organisational networks based on interview data. Sphere: State Government Departments, Diamond: Financial &Banking institutions, Circle: Farmers, Square: Union/Central Government Ministries/Organisations, Triangle: Educational and/or institutions, and Disc: Consulting and Development Agencies.

3.4.2. Knowledge capacity

The lack of adequate expertise and investigative research in the area is another key challenge stated by the respondents. For example, when it comes to the spring-water rejuvenation projects: "*the biggest challenge for us is to understand the hydrogeology of the area*" (SG05). This respondent went on to add that: "*this is just our hypothesis and somebody really needs to go and do the research what is our geology like. We really want to understand the characteristics of our aquifers*" (SG05). Therefore, investigative research from the research community are being sought to empirically understand the actual impact of such projects which the state currently lacks. Lack of climate experts in the state government departments is suggested as another challenge of addressing climate change: "*We have a shortage of climate change experts*" (SG01).

3.4.3. Lack of experienced hydro-geologists

The lack of experienced hydro-geologists in the area who can guide the local communities for carrying out mountain spring-water rejuvenation was stated to be a key challenge although they believe digging trenches in the mountain tops to allow rain water to infiltrate and get stored in the mountain tops. For example, one of the respondents wondered: "*…is it just a through-flow… need to be clarified. But till date, without knowing we are just looking at the geology, at the rock plates, … we just go to the top of the hills and we make the trenches. We go with sort of a thumb rule*" (SG05). Likewise, this respondent went on to state the complete lack of knowledge for them to understand the nature of spring-water "*… it's a black-box for us. Somebody needs to prove it through a scientific research. Is there any "storativity" of water inside the mountains? That is what we want to know.*" (SG05).

3.4.4. Institutional mechanisms and structures

Some of the respondents pointed to the issues related to the lack of institutions for monitoring the changing patterns of spring-water in the region: "*there is no agency as such which is the custodian of data for the springs in mountain regions.*" (SG05). Therefore, suggestions to set up institutions at the national level as well as at the state and regional level to monitor the impacts of from various factors including climate change and change in land-use system. The lack of interaction and coordination with other stakeholders is pointed out as another lacuna in effective adaptation strategy framing: "*People are working in their own silos*" (RA14).

3.5. Opportunities for climate change adaptation

The respondents are not all pessimistic when it comes to climate change impacts in the State. Some of them pointed to the opportunities in acquiring financial supports: "*there is a fund called National Adaptation Fund*" (SG01). Spring-shed development is now being reported to be gaining importance and its importance is being recognised by decision makers and policy makers in the government: "*Sikkim government has been emphasising on the spring-shed development*" (SG05). This respondent went to add that: "*Now the NITIAyog and even the Central Groundwater Board is recognising the importance of the springs and they also now want to explore. So new guidelines have come up wherein they have incorporated springs also a part of groundwater. So far the CGWB has been concentrating in the plain areas.*" (SG05). These are some of the positive developments that the respondents in this research identified as potential opportunities for adaptation.

Political leadership and support from the government have been stated to be positive by one of the respondents: "*At this time we have the right kind of interventions. I think that is going to bring about* [positive change]*… and the leadership is good. The Chief Minister has won many awards. … most eco-friendly state…*" (SG05). This respondent claims that "*he*[the Chief Minister] *understands the issues*". This, he sates is evidenced by the fact that: "*Sikkim is going to bring out the first act in the country linking to sustainable goal*". This respondent is confident that:

"*In a small States…, it is the chief minister. If he understands it, most of the things can be effectively tackled*".

4. Discussion

Climate change is most severely experienced through the medium of water such as droughts and floods. Although it is a global phenomenon, it is experienced differently in different sectors and by different actors depending on socio-economic conditions and the available infrastructure and hence, the engagement of all stakeholders generally leads to a more successful implementation (e.g., Collier et al., 2014). Therefore, it is expected that the perception of climate change impacts and its severity will vary across communities and individuals and so is its perception of prioritising adaptations. The responses in this study shows this variation and in identifying the priority areas of climate change impacts and compliments other similar studies (e.g. Bhadwal et al., 2013) in northern Himalayas but excluded the Sikkim area which this study has done. While the primary concerns of the immediate impacts may vary across individuals and organisations, it is apparent that water availability across seasons, particularly in areas where subsistence agriculture is the primary means for livelihood, is a recurring theme. Therefore, making water available in all seasons is one of the primary concerns of the respondents.

In view of the various potential impacts of climate change on the vulnerable communities' who are depending on the spring-water sources and rainfall which are perceived to be affected by climate change, further research initiatives are required to be undertaken keeping in view the long-term impacts of climate change. The state government of Sikkim has begun documenting the studies being done to understand the spring-water in the state and also the initiatives to preserve them. Other studies such as by Tambe et al. (2012) and others (Chaudhary and Bawa, 2011; Rawat et al., 2011) have documented this growing perception regarding the spring-water sources in other parts of Western Himalayas as well. Some of these studies include the studies done by various development agencies and state government departments. However, a key respondent in this study indicates the lack of adequate understanding about measures being undertaken to revive or preserve these mountain springs as described in Section 3.4.3 above. This is a common and similar challenge like other forest-dependent communities in remote mountain areas (Melnykovych et al., 2018). Therefore, more studies are required to be undertaken by the research community to generate further evidence and knowledge regarding the impacts of spring-water rejuvenation projects being undertaken by the various development agencies in the state. Additionally, capacity building exercises to enable local communities to adequately plan such activities are necessary to enable the effective implementation of such projects. Although there is wide belief that these projects have improved the spring-water recharge, systematic studies that shows conclusively the evidence of its outcome are limited (Tambe et al., 2012).

The potential maladaptation needs to be kept in mind in such vulnerable regions (Juhola et al., 2016). Mountainous regions, such as Sikkim, are particularly vulnerable to landslides and Sikkim is no exception. Therefore, adequate and urgent studies are required to be carried out to assess the geological impacts of spring-water rejuvenation projects in order that it does not contribute towards increased landslide in the region. Such studies are required not only to improve the efficient utilisation of financial and human labour investments in such related projects but to avoid further complications of maladaptation. Other earlier studies, such as by Re et al. (2017) have shown that the participation of local actors enhances the data-interpretation and eventually leads to a more successful diagnosis of the environmental problems. Similarly, stakeholders' consultations lead to greater awareness of the potential impacts (Sacchettini et al., 2012) which even experienced policy makers and researchers might overlook (Wesselink et al., 2011).

Sikkim being a very small state with a limited number of state government departments, the challenges of effective coordination between the various State Government departments is not mentioned by many respondents unlike other bigger Himalayan states such as Himachal Pradesh as reported by Azhoni et al. (2017a, 2017b). The role of political leadership in climate change adaptation was brought out by the respondents similar to which was reported by other studies in another state of India – Himachal Pradesh (Azhoni et al., 2017b). The two states, although varies considerably in size are both in the Himalayan region with similar climate change challenges, such as glacier fed rivers, potential for glacial lakes outburst, changing precipitation patterns and in both the cases the political leadership is apparently aware about the climate change impacts. However, there is a particular departure when the two Himalayan states are compared when it comes to the role of political leadership in the climate change adaptation as perceived by some respondents. While in the case of Himachal Pradesh, one respondent pointed to "political interference" as a negative influence, here in this study a respondent holds a contrasting viewpoint. In both the cases, respondents pointed to the challenges of acquiring historical meteorological data.

It is apparent that the implementation of the State Action Plan on Climate Change is yet to proliferate to other departments. Whereas in many other states in India, including the Himalayan state, Himachal Pradesh, each department has set up a Climate Change Cell to coordinate the implementation of the State Action Plan, such activities are not yet visible in Sikkim. This is despite that some respondents pointed out that the issue of coordinating with other state government department is less, compared to Himachal Pradesh (Azhoni et al., 2017a, 2017b) which is a much larger state.

4.1. Ways forward

The climate change adaptation work in Sikkim is at the initial stage and hence further active involvement from various angles will be necessary. Currently, it is the Science, Technology and Climate Change Department which is coordinating and initiating the actions on climate change. Other State Government departments' involvement is not apparent and their active participation will be necessary for smooth implementation the State Action Plan (Government of Sikkim, 2012) as it has various components. Sikkim also has the advantage of supportive political leadership at the moment as was indicated by the respondents in this research and a stable government. Political leader being a crucial component in adaptation (Meijerink et al., 2015), the state can capitalise on this and make the adaptation implementation more effective.

The responses from the Sikkim State Government Officials and farmers in this research indicate the importance being given by the state government on spring-shed development. The increasing attention being paid by the NITI Ayog (National Institution for Transforming India – a Union Government institution with the Prime Minister as its Chairman which replaced the earlier Planning Commission since 2015), and the Central Groundwater Board on the importance of the springs as an important source of water provides opportunities for the State. So new guidelines are being framed to be included as a part of groundwater although the CGWB has so far concentrated only on the plain areas which indicates the importance of the role of Central Government institutions although water being a state subject in India. The level of coordination between the various stakeholders being an important component of strategizing adaptation options (Gulati et al., 2011), future research can include identification of vulnerable areas by capitalising the work already initiated by the various state government departments and other developmental agencies.

4.2. Spring-water rejuvenation and recharge

Although the groundwater recharge movement in India has a long history and various methods are well documented (Sakthivadivel,

2007), the spring-water rejuvenation is a very nascent initiative and its impacts are yet to be adequately explored by the researchers. Various studies are required to be undertaken to understand some of the challenges of adopting spring-water recharge as a climate change adaptation strategy, particularly when other Himalayan states such as Himachal Pradesh, Uttarakhand and Meghalaya are also planning to adopt such methods. Moreover, since the spring-water rejuvenation is dependent upon other factors such as vegetation cover and physical features of the soil characteristics, there are various aspects that need to be taken before adopting it as viable means of climate change adaptation. Moreover, since infiltration of water depends on the slope of the mountains besides the vegetation cover and the soil characteristics, other local specific and contextual investigations are required to be done before the "success stories" are replicated in other areas. The possibility of maladaptation is real.

4.3. Avoiding maladaptation

Initiatives such as spring-water rejuvenation projects require further investigations with the involvement of geohydrologists and others. Such studies should involve interdisciplinary studies for unambiguous methods of solving the challenges (Rodela and Alašević, 2017) without causing additional unintended consequences (Juhola et al., 2016) such as triggering landslides. The assistance of research institutions in this regards will be necessary in order to ensure that such initiatives do not trigger other risks such as landslides and other unintended effects. For this, the collective actions from other research bodies will be particularly helpful. Successful adaptation includes exploiting available mechanisms and opportunities besides identifying adaptation options to create capacities for human and natural systems to new opportunities (Klein et al., 2014). While identifying new opportunities for adaptation it should not create other cascading effects that increase risks and vulnerability.

5. Conclusion

This study identified research opportunities for further investigation, particularly in the mountainous Himalayan region for adapting to the climate change. Although a number of research is being done to evaluate the vulnerability to climate change and adaptation strategies are being framed at various levels, this study shows many of such studies are yet to make impact on the vulnerable communities in the mountainous regions. It also demonstrates the importance of involving all key stakeholders in the climate change adaptation strategies from the very inception stage. In small states, such as Sikkim in this case study, such integration should be easier than bigger states with different kinds of stakeholders being involved. Understanding the perspectives and concerns of various members enable the formulation of identifying strategies which are beneficial to all affected parties. The results of this research show the need to develop capacities among the vulnerable communities to handle not just extreme events but also to undertake key adaptation strategies in the context of water security. This work has provided specific knowledge gaps that are required to be undertaken by the research community and for providing capacity building measures for water security, based on the perspectives of the vulnerable communities thereby pointing to the importance involving multiple stakeholders in climate change adaptation. Further research needs identified in this research from the perspective of the stakeholders provides opportunities for future research and also valuable information for policy makers and decision makers in the government.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scitotenv.2018.01.112.

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